COMPARISION OF PERFORMANCE ON A TRACKING TASK UNDER SPEED OR ACCURACY INSTRUCTIONS

Yong Hoon Bahk

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

COMPARISION OF PERFORMANCE ON A TRACKING TASK UNDER SPEED OR ACCURACY INSTRUCTIONS

by

Yong Hoon Bahk

March 1980

Thesis Advisor : D.E. Neil

Distribution unlimited; approved for public release

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Comparision of Performance on a Tracking Task under Speed or Accuracy Instructions		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1980
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Yong Hoon Bahk		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE March 1980
		13. NUMBER OF PAGES 49
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Instruction set Speed Accuracy Performance

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research is an investigation of the effects of instruction set on tracking performance. Two sets of instructions, one emphasize accuracy while the other emphasized speed, were tested. Number of errors, time of errors and time to completion under each instruction set were measured. Proportional error in time, mean time of single error and mean interval

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
(Page 1) S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

between successive errors were extracted and discussed. Time to completion under the accuracy condition was approximately four times longer than under the speed condition, but the number and time of errors showed no significant difference between the two experimental conditions.

Distribution unlimited; approved for public release

Comparision of Performance on a Tracking Task under Speed or Accuracy Instructions

by

Yong Hoon Bahk
Lt/Col. Korean Air Force

Submitted in partial fulfillment of the
requirment for the degree of
MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the
NAVAL POSTGRADUATE SCHOOL
March 1980

ABSTRACT

This research is an investigation of the effects of instruction set on tracking performance. Two sets of instructions, one emphasized accuracy while the other emphasized speed, were tested. Number of errors, time of errors and time to completion under each instruction set were measured. Proportional error in time, mean time of single errors and mean interval between successive errors were extracted and discussed. Time to completion under the accuracy condition was approximately four times longer than under the speed condition, but the number and time of errors showed no significant difference between the two experimental conditions.

TABLE OF CONTENTS

I. INTRODUCTION ---------------------------------- 9

A. INSTRUCTION SET ---------------------------- 9

B. SPEED vs ACCURACY ------------------------- 13

C. TRACKING ---------------------------------- 14

D. VISUAL PERCEPTION ------------------------- 15

II. OBJECTIVE ---------------------------------- 18

III. METHODOLOGY -------------------------------- 19

A. TEST SITE AND SUBJECTS -------------------- 19

B. APPARATUS --------------------------------- 19

C. PROCEDURE --------------------------------- 21

D. MEASURES ---------------------------------- 22

E. ANALYSIS OF DATA -------------------------- 23

IV. RESULTS ------------------------------------ 24

A. NUMBER OF ERRORS -------------------------- 24

B. TIME OF ERRORS ---------------------------- 26

C. TIME TO COMPLETION ------------------------ 28

D. MEAN TIME OF SINGLE ERROR ----------------- 30

E. MEAN INTERVAL BETWEEN ERROR --------------- 32

F. PROPORTIONAL ERROR ------------------------ 34

V. SUMMARY OF RESULTS ------------------------- 36

VI. DISCUSSION --------------------------------- 38

VII. CONCLUSION --------------------------------- 41

APPENDIX A : INSTRUCTION TO SUBJECTS ------------ 42

APPENDIX B : RAW DATA -------------------------- 43

APPENDIX C : COMPARISION OF DATA AND CONCLUSION ------ 44

APPENDIX D : WILCOXON TEST(PROCEDURE) ----------- 45

APPENDIX E : CRITICAL REGION OF WILCOXON TEST --------- 46

LIST OF REFFERENCES ----------------------------------- 47

INITIAL DISTRIBUTION LIST ----------------------------- 49

LIST OF TABLES

I. Number of errors(STATISTICS) ------------------ 24

II. Number of errors(TEST) ------------------------ 25

III. Time of errors(STATISTICS) ------------------- 26

IV. Time of errors(TEST) -------------------------- 27

V. Time to completion(STATISTICS) ---------------- 28

VI. Time to completion(TEST) ---------------------- 29

VII. Mean time of single error(STATISTICS) --------- 30

VIII. Mean time of single error(TEST) --------------- 31

IX. Mean interval between error(STATISTIC) -------- 32

X. Mean interval between error(TEST) ------------- 33

XI. Proportional error(STATISTICS) ---------------- 34

XII. Proportional error(TEST) ---------------------- 35

LIST OF FIGURES

1. Apparatus ---------- 20

2. Test ---------- 20

3. Number of errors ---------- 24

4. Time of errors ---------- 26

5. Time to completion ---------- 28

6. Mean time of single error ---------- 30

7. Mean interval between error ---------- 32

8. Proportional error ---------- 34

I. INTRODUCTION

A. INSTRUCTION SET

We are continuously exposed to a wide variety stimuli. A driver sees the traffic about him, hears the noise of the engine, senses the air temperature, etc. However, we do not react equally to all the stimuli impinging upon us at any given time. Our perceptions are selective. We would be overloaded if we had to attend to every stimulus present in our environment (Hilgard et al.,1975). It has been hypothesized that the nervous system must have some kind of register(e.g.,iconic memory for vision or econic memory for auditory) where incoming sensory information is temporarily stored in a rather crude and unanalyzed form (Baron et al.,1977). During the scanning process, certain classes of sensory inputs can be expected to have a higher level of pertinence, (e.g., a mother will hear her baby's cry above the conversation of a roomful of people). Some sort of attention mechanism selects for further processing those sensory inputs that seem most important or pertinent. Determinants of which of many competing stimuli will gain our attention, are not only physical properties of the stimulus like intensity, size, contrast, movement, but certain internal variables, such as motives and expectancies.

In an experimental setting, instructions serve as a means of directing a subject's attention(i.e., producing the desired orientation) to the stimuli and responses of

interest to the experimenter. It is a most important way of controlling a subject's motives and expectancies. Telling the subject what the experiment is all about, what the subject is to do, and how he is to do it are an essential ingredient in experimental research.

Proper instruction of experimental subjects is a prerequisite to effective research (Lucaccini et al.,1968). Clearly, if there is significant variation in the instructions given to subjects, the experimental result is unreliable. Bergum & Lehr(1964) compared the performance of a control group with no special treatment with that of an experimental group receiving 20 cents for each correctly detected signal(positive incentive), and losing 20 cents for each error of omission(negative incentive). The positive incentive group made 98 percent correct detections and the negative incentive group achieved 84 percent while the control group achieved 76 percent. Even minor changes in the experimental procedure in subject performance can lead to statistically significant differences. Fraser(1953) suggested that the presence or absence of the experimenter from the room in which the subject was performing a vigilance task might affect results. In testing the hypothesis using a 60 minute vigilance task, he found that with the experimenter absent a mean of 2.17 signals was missed, with the experimenter present this figure fell to 0.89.

As suggested above, numerous procedural variables, including instructions given to subjects can influence performance. A recommended procedure for good experimental

control is to write out a standarized set of instructions carefully, and read it or have the subject read it or play it on a tape to the subject. Sometimes even the tone of voice and gesture of the experimenter during instruction can affect the results. The experimenter should let subjects know what they are to strive for : speed, accuracy, both, etc. Many experimental tasks are not familiar to subjects. Instructions should be written simply, clearly and directly. Following presentation of instructions, the experimenter should check to ascertain that instructions are understood. Only after the experimenter is sure that instructions are understood completly by the subjects, should he start the experiment.

In summary, performance on any task is in a large part determined by the "set" or predisposition of subjects. This set is partially determined by abilities brought to the experimental setting by subjects and in part determind by conditions which exist within the experimental setting. Frequently, rather subtle factors may impact on subjects and exert a rather profound influence on behavior/performance. This thesis was designed to examine the possible influence of instructions given subjects in the performance of a task.

Madan(1980) in a tracking task instructed subjects to be as accurate as possible in their performance. Therefore, the task based on instruction provided by the experimenter was to minimize errors. Given that instruction set may influence performance it was decided that an attempt should be made to assess the effect of emphasizing speed as opposed to accuracy. If instructional set is capable of influencing

performance by altering the orientation of subjects, it can be postulated that by emphasizing speed with which performance is to be accomplished as opposed to accuracy, more errors should be observed, but subjects should complete the task in a shorter time period.

B. ACCURACY vs SPEED

The time required for and accuracy of movements can be influenced by a number of factors, including the distance moved, the plane and angle of movement in relation to body, the manipulation which will be required at the end of the movement, and the incentive for the movement. Operators can be induced to exchange speed for accuracy (and vice versa) by means of instructions(Fitts,1966). However, if speed stress is pushed beyond the point of achieving reasonable accuracy, performance in terms of rate of transmission deteriorates rapidly. A similar deterioration occurs with excessive emphasis on accuracy(Hillix and Coburn,1961). Conrad(1955) suggests that speed stress is essentially a reaction on the part of a person working on a task that has the effect of worsening his performance beyond what might be expected from the physical characteristics. An experienced operator works a near optimum compromise between speed and accuracy.

C. TRACKING

Tracking can be considered to consist of the execution of accurate movements at the proper time(Poulton,1974). As such, tracking, like most forms of performance consists of doing the right thing in the proper time frame. In tracking, performance is generally concerned with response execution and therefore performance is generally measured in terms of accuracy(Poulton,1966). Further, most tracking research has concentrated on task centered or machine variables. Task centered variables consist of physical requirements of the task itself, display configuration, control system design, etc.(Adams,1961). However, Adams(1961) has also suggested the fact that procedural or man-centered variables are also capable of influencing tracking performance. Such variables include instructions, practice trials, length of practice etc.

Therefore tracking consists of a subject attempting to coordinate his movements, i.e., control of a tracking instrument in terms of the demands made by a stimulus or track. Factors involved in the task and it's complexity include engineering or machine variables and man-centered or procedural variables. Performance has traditionally been measured in terms of the ability of the subject to track the stimulus with the emphasis being placed on accuracy.

The present effort is concerned with the effect of procedural variables, specifically instructions, on task performance.

D. VISUAL PERCEPTION

Sensation is the process by which stimuli are detected. Among all the sensory processes, vision is the most accurate and reliable for the human. Galenter(1962) points out that one can see a candle 30 miles away on a dark night. As stimuli, light enters the eye by first passing through a transparent cover called the cornea and then through the pupil opening that is controlled by the iris. These control both the amount of light allowed in and the sharpness of the focused image within the eye. Pupil size is a compromise between maximum sharpness and maximum light entry. Pupil size also varies with emotional states like when males are shown pictures of nude females, the pupil expands (Hess and Polt,1960). The lens bends the light rays to focus upon the retina in the back of the eye. The curvature of the lens can be changed in accordance with the distance of the object one wishes to view in the external world. This change is accomplished by the ciliary muscles.

Perception is the process by which a person converts sensory messages into understandable forms. A visual sensory stimulation is maintained in an iconic memory(a visual sensory storage) for less than a second, and the span of apprehension in a single glance is no bigger than five bits (Sperling,1960). One can not prolong the life of visual information in the sensory storage without using the primary(or short-term) memory. The information which is in the short-term memory is still subject to decay, and it can be stored in the long-term memory by self rehearsal.

Visual perception is a complex process that involves the interaction between the sensory process and cortex of the brain. One can easily differentiate a miniature car that is close from a real one that is further away even though the images on the retina are almost the same. This perceptual skill relies upon various combination of cues. Although a single cue by itself may be unreliable, by combining cues we can arrive at an accurate picture of the external situation.

A man with binocular vision has advantages over a man with monocular : not only his total visual field is larger, so that he can see more at once, but also he has stereoscopic vision. In stereoscopic vision the two eyes cooperate to yield the experiences of solidity and distance. A man with monocular vision, can create a three dimensional configuration by using his visual experiences to improve his depth perception.

Visual perception is oriented toward things rather than toward the sensory image. One's perceptual experiences are not isolated. A well known object is perceived as permanent and stable regardless of illumination.

The tendency to see an object as the same size regardless of distance is called size constancy. The fact that an object appears to retain the same position, even as we move about, is known as location constancy. The tendancy to see an object's shape as unchanging regardless of the viewing angle is called shape constancy.

Perception is therefore concerned with the manner in which an individual perceives and interprets incoming

stimuli. Performance is therefore dependant upon the stimuli, visual functioning and observer's interpretation. Performance can be modified by altering stimuli, or providing conditions which will degrade or impair visual functioning, or by introducing variables which may influence an observer's interpretation of stimuli. Given that stimuli and conditions affecting visual function remain constant, it should be possible to modify one's interpretation of the stimulus environment and thereby influence his behavior. Instructional set should modify one's interpretation of stimuli and this new interpretation should be reflected in performance.

II. OBJECTIVE

This experiment investigated the relationship between speed and accuracy with changing instructions to the subjects.

The present effort was designed to examine the influence of instruction on performance in a tracking task. As suggested above instructions served to orient the operator's attention and/or perception of his environment. In tracking the emphasis has traditionally been placed on the accuracy with which a subject can track a stimulus input with the independant variable(s) normally being machine oriented. Madan(1980) examined performance on a tracking task in which his instructions were accuracy oriented.

The current effort will duplicate Madan's study with a major change in the procedural variables of instructions provided to subjects. Specifically where Madan instructed subjects to perform as accurately as possible, the present study compared instructions to the subject emphasizing accuracy and speed with which subjects were able to complete the task. Results should indicate the impact of the procedural variables of instruction on tracking performance.

III. METHODOLOGY

As stated earlier, the goal of this experiment was to compare tracking performances under two different instructional sets, one emphasizing speed, the other emphasizing accuracy. The results of the task were evaluated by number of errors, duration of total errors and the time to completion. The task was to move a probe between two guard rails and an underlying meshboard. Any touch of the probe to a guard rail or meshboard was counted as an error, and it's duration was measured.

A. TEST SITE AND SUBJECTS

The experiment was performed in the Man-Machine System Design Laboratory at the United States Naval Postgraduate School in Monterey, California. Nineteen military male officer students at the School served as subjects. All were volunteers from among associates of the experimenter. No positive external reinforcements were given, but all the subjects showed eagerness to participate. Their ages ranged from 28 to 40 with an average of 34.6. None of the subjects was known to have mental or physical disorders. None had previously performed a tracking task of this nature.

B. APPARATUS

The tracking apparatus(see Fig.1) was placed on a black table top in a sound attenuated booth(see Fig.2). The track apparatus was connected to a Digital PDP8/E Laborotory Computer which counted the number of errors, measured the

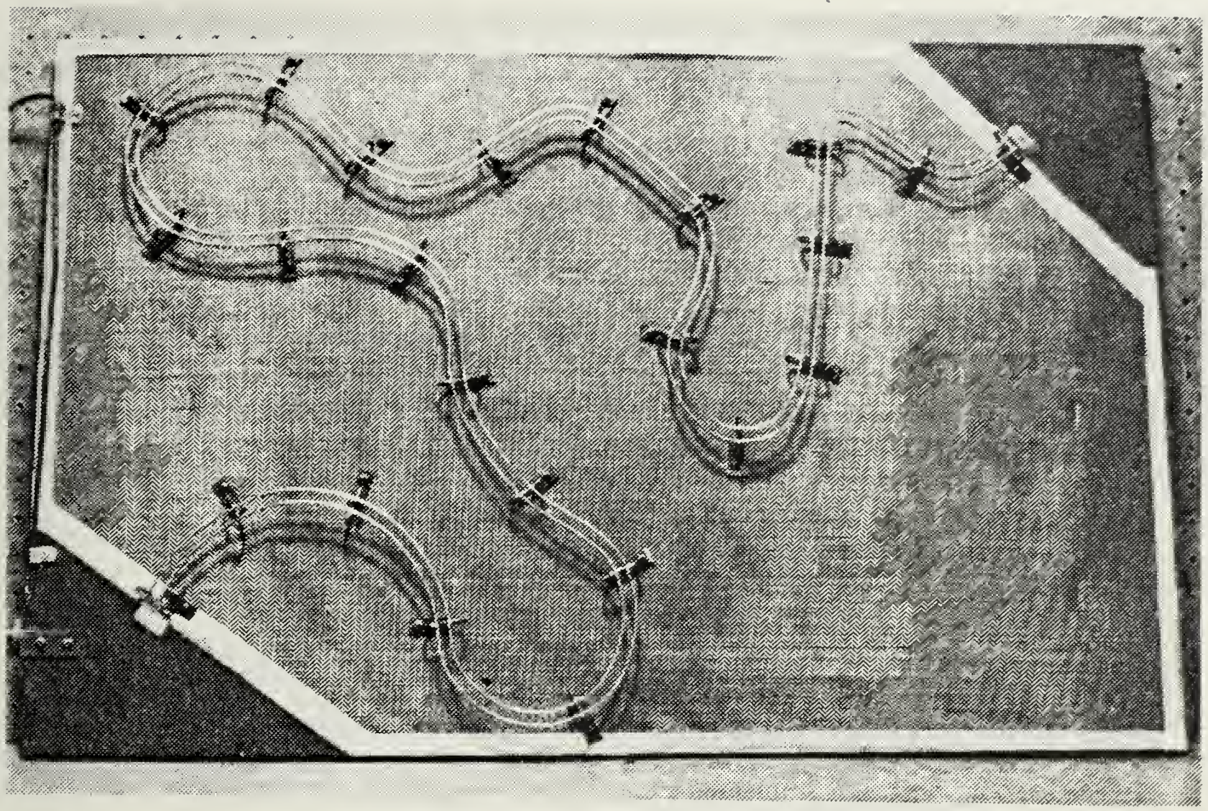

Figure 1. Apparatus

Figure 2. Test

duration of errors and time to completion. Every subject was instructed to touch both the start point when a trial was commenced and to touch the end point when the trial was completed. Start and end points consisted of contacts which would alert the computer that a trial had begun or ended. The computer could recognize and count any touch longer than 14 nano-sec(1.4E-10 seconds).

C. PROCEDURE

All subjects were tested individually. The test times were arranged at the subject's convenience. Test trials were seperated by 30 minutes to prevent interaction between participants. Latin square technique was applied to assign the sequence of speed and accuracy condition.

1. Before starting the experiment, each subject was asked whether there were any factors of which they were aware which could influence the results.

2. The instructions were given to each subject to read. After reading the instruction, they were allowed to ask any questions of the experimenter.(See Appendix B)

3. All subjects were allowed two practice trials.

4. The first test run was preceded by the the instruction "This time your goal is to do the task as FAST(or ACCURATELY) as you can."

The second test run was preceded by the instruction "Now your goal is doing the tracking as ACCURATELY(or FAST) as you can."

5. After completion of the experiment, each subject was asked if he had any comments.

D. MEASURES

All data were collected and measured by means of the PDP.8/E laboratory computer.

Measures included :

1. Number of Errors(NE) (i.e., the number of times the probe touched the rail or mesh)

2. Time of errors(TE) (i.e., the cummulative duration of touching the rail or mesh)

3. Time to completion(TC) (i.e., the total traverse time between the start point and the end point)

4. Mean time of single error(MTE) (i.e., the time of error divided by number of errors)

5. Mean interval between error(MIE) (i.e., the time to completion divided by number of errors)

6. Proportional error in time(PE) (i.e., the time of errors divided by time to completion)

The following acronyms were utilized :

NES : Number of errors(NE) in speed condition.

NEA : Number of errors(NE) in accuracy condition.

TES : Time of errors(TE) in speed condition

TEA : Time of errors(TE) in accuracy condition

TCS : Time to completion(TC) in speed condition

TCA : Time to completion(TC) in accuracy condition

MTES : Mean time of single error(MTE) in speed condition

MTEA : Mean time of single error(MTE) in accuracy condition

MIES : Mean interval between errors(MIE) in speed condition

MIEA : Mean interval between errors(MIE) in accuracy

PES : Proportional error(PE) in speed condition

PEA : Proportional error(PE) in accuracy condition

E. ANALYSIS OF DATA

An examination of the data revealed that parametric techniques could not be applied, even after attempts to transform the data. Therefore non-parametric techniques were applied. In order to determine the effect of different instructions, the Wilcoxon Matched-pairs Signed-ranks Test was applied to the data obtained under two instructions emphasizing Speed or Accuracy(Siegel,1956). Since N was always 19, the critical region was $T \leq 46$ at significance level $\alpha = 0.05$. (see APPENDIX.E).

IV. RESULTS

The analysis of data showed the following results :

A. NUMBER OF ERRORS(NE)

Sampling distribution and statistics of obtained number of errors are shown in Fig. 3 and Table I.

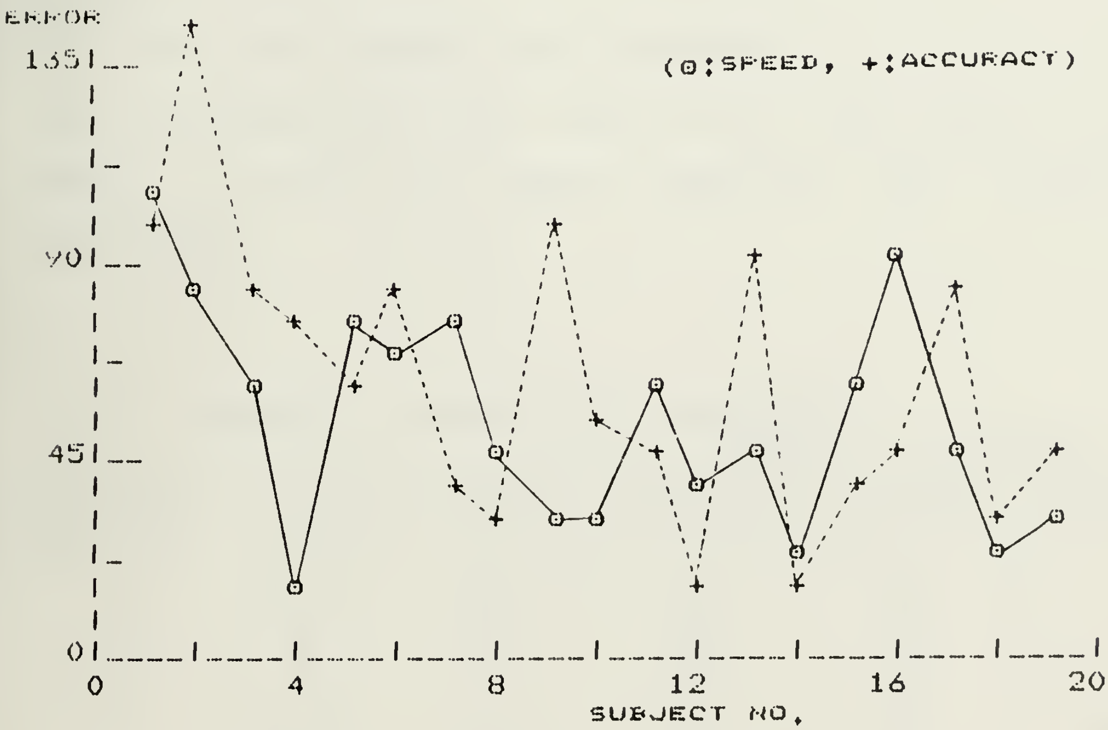

FIGURE 3. NUMBER OF ERRORS

Table I. Number of Errors(STATISTICS)

	NES	NEA
MEAN	55.3	64.8
VARIANCE	673	110
STD DEV.	25.9	33.3
MEDIAN	49	55
TRIMEAN	51.7	59
MIDMEAN	53.5	62.1
RANGE	88	128
MID RANGE	62	79
COEF. SKEWNESS	0.31	0.52
COEF. KURTOSIS	-1.08	-0.47

Hypothesis Test

Ho : Different Instructions have no differential effect on number of errors. (NES=NEA)

H1 : Different Instructions have differential effect. (NES≠NEA)

The computed T was 55(Table II) and it was out of the critical region.

Decision: Accept Null Hypothesis

The conclusion is that there is no difference between number of errors in speed condition and in accuracy instruction.

Table II. Number of Errors(TEST)
(error per traverse)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	106	104	2	+1	
2	87	143	¯56	17	
3	65	84	¯19	8	
4	18	79	¯61	18	
5	79	66	13	+3	
6	71	86	¯15	6	T=55
7	78	42	36	+13	
8	46	32	14	+5	
9	34	102	¯68	19	
10	30	55	¯25	11	
11	64	49	15	+7	
12	43	15	28	+12	
13	45	97	¯52	16	
14	25	20	5	+2	
15	62	40	22	+10	
16	95	45	50	+15	
17	49	86	¯37	14	
18	23	36	¯13	4	
19	31	51	¯20	9	

B. TIME OF ERRORS(TE)

Sampling distribution and statistics of the cumulative durations of errors are shown in Fig.4 and Table III.

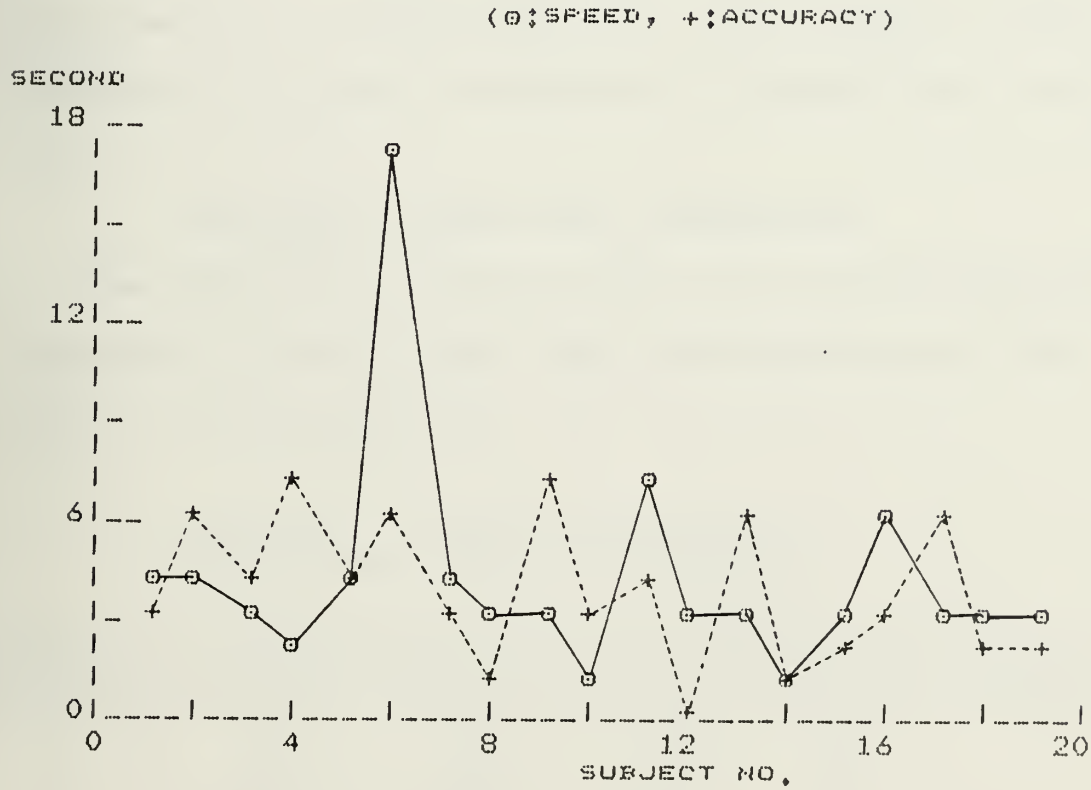

FIGURE 4. TIME OF ERRORS

Table III. Time of errors(STATISTICS)

	TES	TEA
MEAN	4.57	4.15
VARIANCE	12.3	4.26
STD DEV.	3.51	2.06
MEDIAN	3.75	3.81
TRIMEAN	3.85	3.97
MIDMEAN	3.86	4.07
RANGE	16.6	6.81
MIDRANGE	9.54	4.36
COEF. SKEWNESS	2.91	0.25
COEF. KURTOSIS	8.42	-1.18

Hypothesis Test

Ho : Different Instructions have no differential effect on cumulative time of errors. (TES=TEA)

H1 : Different Instructions have differential effect. (TES≠TEA)

The computed T was 83(Table IV), which failed to allow for rejection of the Null Hypothesis at significance level of 0.05.

Decision : Accept Null Hypothesis.

The conclusion is that there is no difference between cumulative time of error with speed instruction(TES) and accuracy instruction(TEA).

Table IV. Time of Errors(TEST)

(second per error)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	4.76	3.44	1.32	6	
2	4.9	6.01	¯1.11	−4	
3	3.63	4.84	¯1.21	−5	
4	2.49	7.77	¯5.28	−18	
5	4.01	4.7	¯0.69	−2	
6	17.8	6.01	11.8	19	T=83
7	4.81	3.28	1.53	8	
8	3.07	1.54	1.53	9	
9	3.44	7.57	¯4.13	−17	
10	1.41	3.58	¯2.17	−11	
11	7.2	4.41	2.79	16	
12	3.67	0.96	2.71	15	
13	3.75	6.2	¯2.45	−13	
14	1.23	1.81	¯0.58	−1	
15	3.96	2.42	1.54	10	
16	6.26	3.81	2.45	14	
17	3.97	6.27	¯2.3	−12	
18	3.32	2	1.32	7	
19	3.09	2.26	0.83	3	

C. TIME TO COMPLETION(TC)

Sampling distribution and statistics of time to completion are shown in Fig. 5 and Table V.

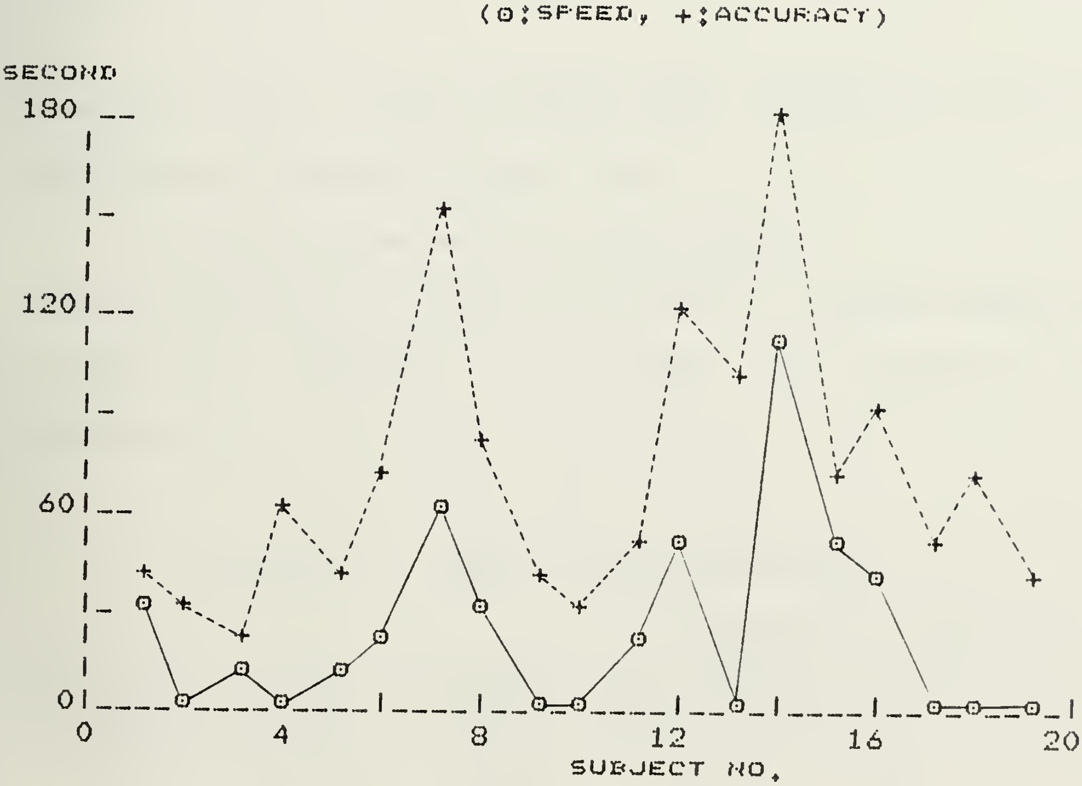

FIGURE 5. TIME OF COMPLETION

Table V. Time to completion(STATISTICS)

	TCS	TCA
MEAN	28.1	73.7
VARIANCE	879	1802
STD DEV.	29.7	42.4
MEDIAN	14.3	61.9
TRIMEAN	19.8	64.4
MIDMEAN	20	63.5
RANGE	115	154
MIDRANGE	60.4	104
COEF SKEWNESS	1.56	1.18
COEF KURTOSIS	2.03	0.464

Hypothesis test

Ho : Different Instructions have no differential effect on time to completion. (TCS=TCA)

H1 : Different Instructions have differential effect (TCS≠TCA)

Computed T was 0(zero, Table. VI), indicating that every subject had a larger TCA than TCS.

Decision : Reject Null Hypothesis.

The conclusion is that the time of traverse(completion) in accuracy condition is greater than that of speed condition.

Table VI. TIME TO COMPLETION(TEST)

(second per traverse)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	32.7	44.4	¯11.7	2	
2	9.69	36.2	¯26.5	5	
3	14.3	26.6	¯12.3	3	
4	3.07	61.9	¯58.8	14	
5	11.8	42.5	¯30.7	6	T=0
6	23.8	79.6	¯55.8	13	
7	66.8	157	¯90.7	18	
8	39.2	82.6	¯43.4	10	
9	5.38	46.3	¯40.9	9	
10	4.86	31.4	¯26.5	4	
11	22.9	54.1	¯31.2	7	
12	52.1	124	¯71.9	17	
13	8.56	104	¯95.6	19	
14	118	181	¯62.9	15	
15	58.9	70.4	¯11.5	1	
16	44	91.1	¯47.2	11	
17	6.6	54.2	¯47.6	12	
18	4.26	71.2	¯66.9	16	
19	6.73	40.6	¯33.9	8	

D. MEAN TIME OF SINGLE ERROR(MTE)

The Mean time of single Error was extracted by the total time of error(TE) divided by the total number of errors(NE) (MTES=TES/NES and MTEA=TEA/NEA).

Sampling distribution and statistics are shown in Fig. 6

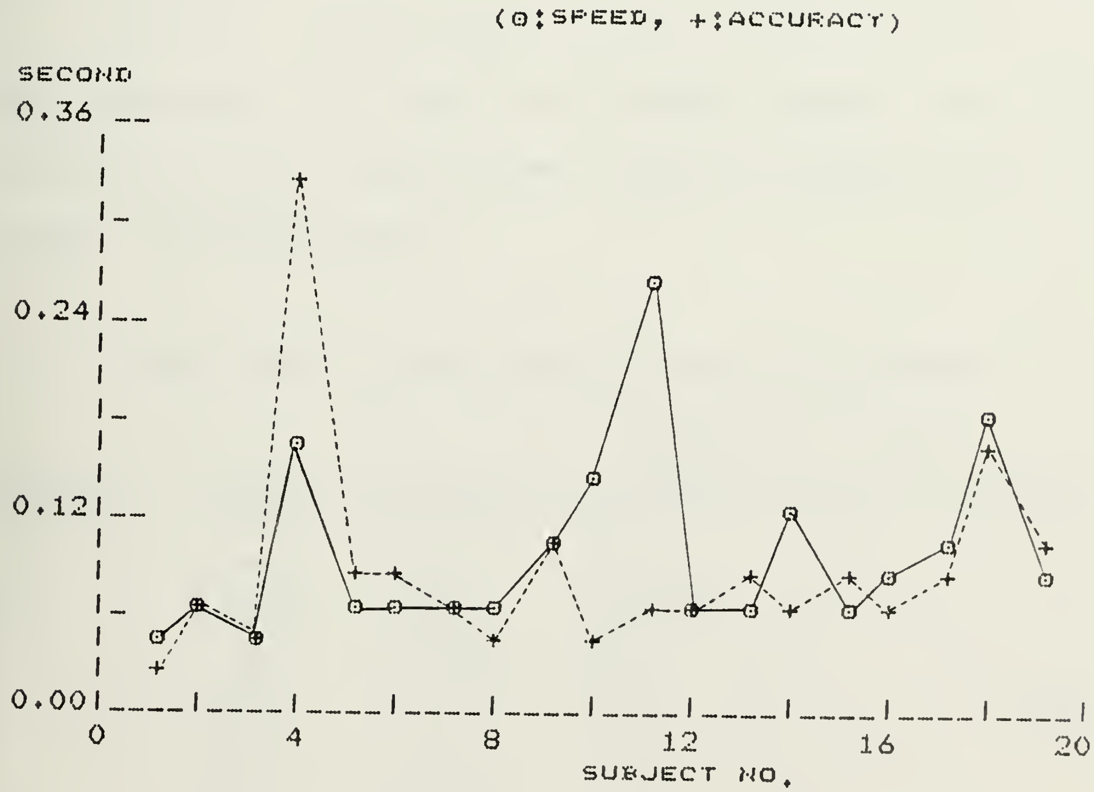

FIGURE 6. MEAN TIME OF SINGLE ERROR

Table VII. Mean time of Error(STATISTICS)

	MTES	MTEP
MEAN	0.087	0.0665
VARIANCE	0.00245	0.0003
STD DEV.	0.0495	0.0175
MEDIAN	0.0667	0.0651
TRIMEAN	0.0726	0.0663
MIDMEAN	0.0746	0.0666
RANGE	0.206	0.0653
MIDRANGE	0.148	0.0657
COEF SKEWNESS	2.02	-0.0446
COEF KURTOSIS	3.99	-0.778

Hypothesis Test

Ho : MTES=MTEA

H1 : MTES≠MTEA

Computed value was T=50, which is out of the critical region(Table VIII).

Decision : Accept Ho.

The conclusion is that the average duration of single error(touch) was same between speed experiment(MTES) and accuracy experiment(MTEA).

Table VIII. Mean time of single error(TEST)

(Second per Touch)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	0.0449	0.0331	0.0118	4	
2	0.0563	0.042	0.0143	5	
3	0.0558	0.0576	¯0.00177	−1	
4	0.138	0.0984	0.04	15	
5	0.0508	0.0712	¯0.0205	−11	
6	0.251	0.0699	0.181	19	T=50
7	0.0617	0.0781	¯0.0164	−6	
8	0.0667	0.0481	0.0186	8	
9	0.101	0.0742	0.027	14	
10	0.047	0.0651	¯0.0181	−7	
11	0.112	0.09	0.0225	13	
12	0.0853	0.064	0.0213	12	
13	0.0833	0.0639	0.0194	10	
14	0.0492	0.0905	¯0.0413	−16	
15	0.0639	0.0605	0.00337	2	
16	0.0659	0.0847	¯0.0188	−9	
17	0.081	0.0729	0.00811	3	
18	0.144	0.0556	0.0888	18	
19	0.0997	0.0443	0.0554	17	

E. MEAN INTERVAL BETWEEN COMMITTING ERROR(MIE)

The mean interval between error(MIE) was extracted by the time to completion(TC) divided by number of errors(NE), such that MIES=TCS/NES and MIEA=TCA/NEA. Sampling distribution and statistics are shown in Fig. 7 and Table IX.

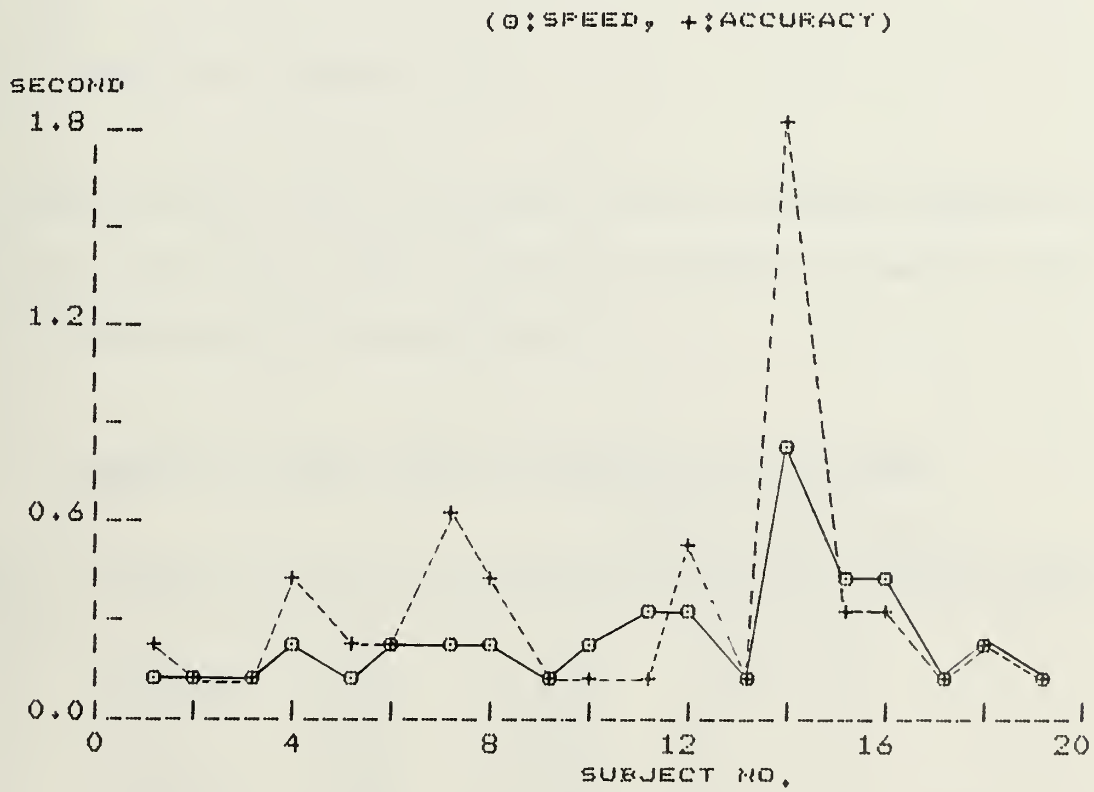

FIGURE 7. MEAN INTERVAL BETWEEN TOUCH

Table IX. Mean interval between error(STATISTICS)

	MIES	MIEA
MEAN	0.618	1.97
VARIANCE	1.090	6.36
STD DEV.	1.04	2.52
MEDIAN	0.22	0.925
TRIMEAN	0.364	1.11
MIDMEAN	0.310	1.12
RANGE	4.59	8.77
MIDRANGE	2.41	4.64
COEF SKEWNESS	3.31	2.01

Hypothesis Test

Ho : MIES=MIEA

H1 : MIES≠MIEA

Computed value(Table.X) was T=0, such that every subject showed that MIES < MIEA.

Decision : Reject Ho.

The conclusion is that average interval between committing errors in time with speed experiment(MIES) was smaller than that of accuracy experiment(MIEA).

Table X. Mean interval between errors(TEST)

(second per touch)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	0.314	0.427	¯0.113	1	
2	0.0678	0.253	¯0.185	3	
3	0.17	0.317	¯0.147	2	
4	0.0389	0.784	¯0.745	12	
5	0.179	0.644	¯0.465	6	
6	0.276	0.925	¯0.649	10	T=0
7	1.59	3.75	¯2.16	17	
8	1.23	2.58	¯1.36	15	
9	0.0527	0.454	¯0.401	5	
10	0.0884	0.57	¯0.482	7	
11	0.468	1.1	¯0.636	9	
12	3.48	8.27	¯4.8	19	
13	0.0882	1.07	¯0.985	13	
14	5.88	9.03	¯3.14	18	
15	1.47	1.76	¯0.288	4	
16	0.977	2.03	¯1.05	14	
17	0.0767	0.63	¯0.554	8	
18	0.118	1.98	¯1.86	16	
19	0.132	0.797	¯0.665	11	

F. PROPORTION OF ERROR(PE)

The percent of errors in cumulative time was extracted by the time of errors(TE) divided by the time to completion (TC), such that PES=TES/TCS and PEA=TEA/TCA. Sampling distribution and statistics of proportional error are shown in Fig. 8 and Table XI.

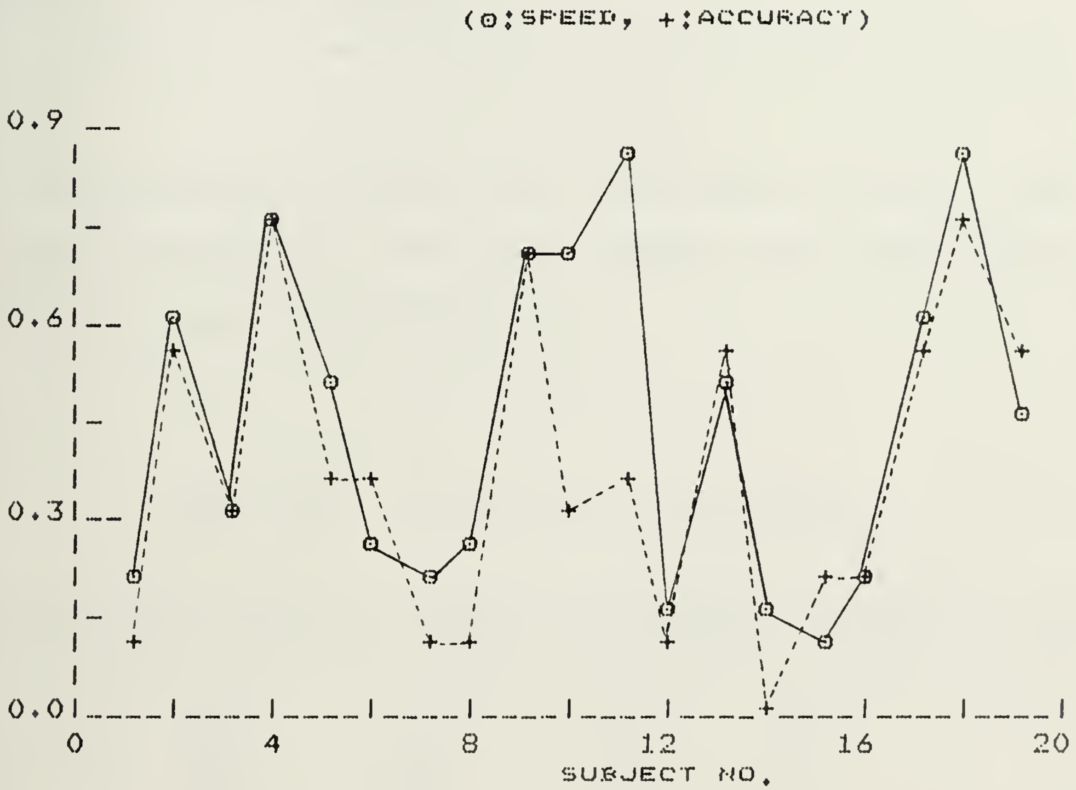

FIGURE 8. PROPORTIONAL ERROR

Table XI. Proportional error(STATISTICS)

	PES	PEA
MEAN	0.356	0.078
VARIANCE	0.071	0.003
STD DEV.	0.266	0.055
MEDIAN	0.314	0.076
TRIMEAN	0.327	0.074
MIDMEAN	0.324	0.072
RANGE	0.801	0.174
MIDRANGE	0.411	0.095
COEF SKEWNESS	0.355	0.425
COEF KURTOSIS	-1.280	-1.090

Hypothesis Test

Ho : PES=PEA

H1 : PES≠PEA

Computed value was again T=0(Table XII), such that every subject recorded PES>PEP.

Decision : Reject Ho.

The conclusion is that the proportion of error under the speed instructions (PES) was greater than that under the accuracy instructions(PEA).

Table XII. Proportional error(TEST)

(percent)

SUBJ.NO	SPEED	ACCURACY	DIFFERENCE	RANK(D)	PARTIAL SUM
1	14.6	7.75	6.82	6	
2	50.6	16.6	34	12	
3	25.4	18.2	7.21	7	
4	81.1	12.6	68.6	18	
5	33.9	11.1	22.8	10	T=0
6	75.1	7.55	67.5	17	
7	7.2	2.08	5.12	3	
8	7.82	1.86	5.96	4	
9	63.9	16.4	47.6	15	
10	29	11.4	17.6	9	
11	31.4	8.15	23.2	11	
12	7.04	0.774	6.26	5	
13	43.8	5.95	37.9	13	
14	1.05	1	0.0429	1	
15	6.73	3.44	3.29	2	
16	14.2	4.18	10.1	8	
17	60.2	11.6	48.6	16	
18	77.9	2.81	75.1	19	
19	45.9	5.56	40.4	14	

V. SUMMARY OF RESULTS

A. NUMBER OF ERRORS(NE)

Slightly more than half(10 of 19 subjects) recorded more errors during the accuracy experiment(med : 49 errors) than trials emphasizing speed(med : 55 errors). However there was no statistically significant difference between the number of errors in the speed experiment and accuracy experiment.

B. TIME OF ERRORS(TE)

Half(10 of 19 subjects) recorded longer accumulated time of errors under speed emphasis(med : 3.75 sec) than accuracy emphasis(med : 3.81 sec). The difference was not statistically significant.

C. TIME TO COMPLETION(TC)

The completion time of accuracy portion(med : 61.9 sec) was approximately four times that of speed emphasis(med : 14.4 sec).

D. MEAN TIME OF SINGLE ERROR(MTE)

The mean time of single error under the accuracy emphasis(med : 0.065sec) was shorter than that of speed portion(med : 0.074 sec). But the difference was not statistically significant.

E. MEAN INTERVAL BETWEEN ERRORS(MIE)

The average interval between committing errors in

accuracy portion(med : 0.79 sec) was approximately four times that of speed experiment(med : 0.204 sec). This difference was statistically significant.

F. PROPORTION OF ERROR(PE)

The average proportional error under the speed emphasis(med : 38.8 percent) was approximately five times that of the proportion errors under the accuracy emphasis(med : 7.9 percent). This difference was statistically significant.

VI. DISCUSSION

The results indicated that under the accuracy conditions subjects took roughly four times longer to complete the task than under the speed conditions. Neither number of errors nor accumulated time of errors showed a significant difference between the two conditions.

Craik(1948) assumed that the speed of a continuous performance was limited by times, first to observe and decide upon the correction for misalignments (response initiation time), and second, to carry out the correction (time of movement or correction).

(a) When actions have to be carried out meticulously and the display is static, subjects may well monitor the end of movements as well as earlier significant points (accuracy experiment). This extra monitoring increases the total time of successive responses.

(b) When the action does not have to be as precise(speed experiment), the extra monitoring time is likely to be eliminated, and the speed of performance will be reduced.

Further, in a key pressing task, Davis(1956) observed that response accuracy was increased if subjects did not monitor performance. The suggestion was that observer's attention may in fact inhibit the response dimmension actually being sought. In the present task, it can be postulated that this same phenomena may have actually

degraded performance as opposed to improving it as would intuitively have been expected.

It was observed that :

1. The speed of the moving probe in the speed experiment (8.39 cm per sec) was faster than accuracy experiment(1.94 cm per sec). This assumes a constant rates of travel through the experiment.

2. During the speed experiment, the subjects did not concentrate their efforts on minimizing errors but on time to complete the task. Performance suggested that subjects continued to allow the probe to touch the rail or mesh. This practice allowed them to minimize the time required to complete the task. It can be hypothesized that this strategy of touching the probe to the rail or mesh reduced the opportunity for subjects to commit additional errors.

3. During the accuracy portion of the exeriment, most subjects stopped their probe to correct any error/touch. This practice may have contributed more errors by providing additional opportunity for error/touch commission.

4. Further, several subjects indicated that tremor influenced their performance during the accuracy portion of the experiment. No subjectreported tremor during their speed trials. Yong(1933) suggested that attempts to control tremor usually aggravates the condition. Therefore, in the present study, the contribution of tremor may have led to degraded performance in the accuracy condition. That is, instructions and resulting subject orientations may have actually served to degrade performance on the accuracy dimension. It can be postulated that the factors suggested above combined to

produce a degradation of speed and no improvement in accuracy on the task emphasized in the present experiment.

VII. CONCLUSIONS

It was concluded that :

1. There was no differences in the number of errors or the accumulated time of errors between the results of the speed experiment and the accuracy experiment.

2. There was significant difference in time to completion between the speed experiment and the accuracy experiment.

3. Proportional errors in durations of touch showed a significant difference between the speed experiment and the accuracy experiment.

4. Attempts by subjects to maximize accuracy actually seemed to impair their ability to reduce error, while simultaneously increasing their time to complete the task.

Therefore, in the present task, instructional set degraded the performance dimensions, the instructions were actually attempting to enhance. This condition can, in part, be attributed to the development of performance strategies which may have served to increase the opportunity to commit errors and the production of tremor. These two conditions apparently worked in opposition to the accuracy instructions.

APPENDIX A

INSTRUCTION

The most general goal of a tracking task is completion of the task in minimum period with minimum error.
This experiment is designed to compare the result of an experimental tracking task with speed and with precision.
Read following instructions carefully and ask question to the experimenter if there is.

1. Your task is to guide the probe through the wires from the start point to the end point.

2. Hold the plastic handle of the probe where ever you feel comfortable.

3. The tracking hand and arm should not rested on the table or the test board.

4. The probe should not touch the wires or the mesh below them, unless it will make errors and counted by the computer.

5. Touch the start point when you start a run. Completing the run, touch the end point, immediately.

6. Your experiment is composed of two runs : one is a speed experiment and the other is an accuracy experiment.

7. You can have preliminary trials up to two runs.

8. If you have any question, ask the experimenter by your words . The experimenter will answer 'YES' or 'NO' only.

9. If you have no questions any more, wait the starting signal from the experimenter.

10. ( ) Your first run is a speed experiment. Speed is very important. Do it as fast as you can.
( ) Your first run is an accuracy experiment. Accuracy is very important. Do it as accurately as possible.

11. ( ) Your second run is an accuracy experiment. Accuracy is very important. Do it as accurately as you can.
( ) Your second run is a speed experiment. Speed is very important. Do it as fast as you can.

12. Please tell the experimenter any comment if you have.

APPENDIX B

RAW DATA

SUBJ. NO.	NES	NEA	TES	TEA	TCS	TCA
1	106	104	4.76	3.44	32.7	44.4
2	87	143	4.9	6.01	9.69	36.2
3	65	84	3.63	4.84	14.3	26.6
4	18	79	2.49	7.77	3.07	61.9
5	79	66	4.01	4.7	11.8	42.5
6	71	86	17.8	6.01	23.8	79.6
7	78	42	4.81	3.28	66.8	157
8	46	32	3.07	1.54	39.2	82.6
9	34	102	3.44	7.57	5.38	46.3
10	30	55	1.41	3.58	4.86	31.4
11	64	49	7.2	4.41	22.9	54.1
12	43	15	3.67	0.96	52.1	124
13	45	97	3.75	6.2	8.56	104
14	25	20	1.23	1.81	118	181
15	62	40	3.96	2.42	58.9	70.4
16	95	45	6.26	3.81	44	91.1
17	49	86	3.97	6.27	6.6	54.2
18	23	36	3.32	2	4.26	71.2
19	31	51	3.09	2.26	6.73	40.6

NES = NUMBER OF ERRORS IN SPEED EXPERIMENT
NEA = NUMBER OF ERRORS IN ACCURACY
TES = CUMULATIVE TIME OF TOUCH IN SPEED EXPERIMENT (SECOND)
TEA = CUMULATIVE TIME OF TOUCH IN ACCURACY (SECOND)
TCS = TIME TO COMPLETION IN SPEED EXPERIMENT(SECOND)
TCA = TIME TO COMPLETION IN ACCURACY (SECOND)

Appendix C

COMPARISION OF RESULTS AND CONCLUSIONS

		RESULT		RATIO	CONCLUSION
		SPEED	ACCURACY	SPEED:ACCURACY	
Number of Errors (NE) -errors-	MEAN	54.2	68.0	1 : 1.25	NES=NEP
	MED	48.0	63.0	1 : 1.31	
	VAR	610	1110	-	
Total Time of Errors (TE) -second-	MEAN	4.46	4.31	1.03 : 1	TES=TEP
	MED	3.71	4.55	1 : 1.23	
	VAR	10.7	3.81	-	
Time to Completion (TC) -second-	MEAN	25.1	65.8	1 : 2.62	TTS<TTP
	MED	10.5	54.2	1 : 5.16	
	VAR	814	1940	-	
Mean Time of Single Error (MTE) -second-	MEAN	0.087	0.066	1.31 : 1	MTES=MTEP
	MED	0.074	0.065	1.15 : 1	
	VAR	0.002	0.0003	-	
Mean Interval between Error (MIE) -second-	MEAN	0.552	1.73	1 : 3.13	MIES<MIEP
	MED	0.204	0.79	1 : 3.87	
	VAR	0.961	2.42	-	
Proportional Error (PE) -percent-	MEAN	39.5	11.2	3.53 : 1	PES>PEP
	MED	38.8	7.9	4.91 : 1	
	VAR	7.14	1.05	-	

APPENDIX D

WILCOXON MATCHED-PAIR SIGNED-RANK TEST(PROCEDURE)

1. For each subject's result, determine the signed difference(D) between speed experiment and accuracy experiment.

2. Rank these D's without respect to sign.

3. Affix to each rank the sign(+ or -) of the D which at represent.

4. Determine T='Number of The smaller sums of the like-signed ranks'.

5. By counting, determine N='The total number of D's having a sign'.

6. Compare T with the critical region with APPENDIX.F having N.

(Siegel,1956 page 83)

APPENDIX E

Table of Critical Values of T in the Wilcoxon Matched-pairs Signed-ranks Test

N	Level of Significance for one-tailed test		
	.025	.01	0.005
	Level of Significance for Two-Tailed test		
	.05	.02	.01
6	0	-	-
7	2	0	-
8	4	2	0
9	6	3	2
10	8	5	3
11	11	7	5
12	14	10	7
13	17	13	10
14	21	16	13
15	25	20	16
16	30	24	20
17	35	28	23
18	40	33	28
19	46	38	32
20	52	43	38
21	59	49	43
22	66	56	49
23	73	62	55
24	81	69	61
25	89	77	68

(Siegel, 1956)

N was always 19 (no pair of data showed tie) and Critical Region was $T \leq 46$ at significance level $\alpha = 0.05$ (Two tail test)

LIST OF REFFERENCES

Adams, J.A., Human tracking behavior. Psychological Bulletin, vol. 58, pp. 55-79, Jan., 1961

Baron, R.A., Byrne, D. and Kantowitz, B.H., Psychology -Understanding Behavior. Philadelphia : W.B. Saunders, 1977

Bergum, B.O. and Lehr, D.J., Monetary incentives and vigilance. Journal of Experimental Psychology, vol. 67, pp. 197-198, 1964

Conrad, R., Some effect on performance of changes in perceptual load, Journal of Experimental Psychology, vol. 49, pp. 313-322, 1955

Craik, K.J., Psychology and Physiological aspect of control mechanism with special reference to tank gunnery. Part I. Medical Research Council(Great Britain), Military Personnel Research Committee, B.P.C. Aug. 1943

Davis, R., The limits of psychological refractory period, Quarterly Journal of Experimental Psychology vol. 8, pp. 24-38, 1956

Fitts, P.M., Cognitive aspect of information processing : III.Set for speed vs accuracy, Journal of Experimental Psychology, vol. 71, pp. 849-857, 1966

Fraser, D.C., The relationship of an environmental variable to performance in a prolonged visual task. Quarterly Journal of Experimental Psychology, vol.5, pp. 31-32, 1953

Galenter, E., Contemporary psychophysics. New York : Holt, Rinehart and Winston, 1962

Hess, E.H. and Polt, J.M., Pupil size as related to the interest value of visual stimuli. Science, vol. 132, pp. 349-350, 1960

Hilgard, E.R., Atkinson, R.C. and Atkinson, R.L., Introduction to psychology, New York : Harcourt B. J. Inc., 1975

Hilix, W.A. and Coburn, R., Human factors in keyset design. Research Rprt No. 1023, U.S. Naval Electronic Lab., Mar. 1961

Kimotsuki, K., On the measurement of the speed of finger motion, Journal of Science Lab., vol.43, pp. 243-252, 1967

Lucaccini, L.F., Freedy, A. and Lyman, J., Motional factors in vigilance effects of instructions performance in a complex vigilance task, Perceptual and Motor Skills, vol.26, pp. 783-786, 1968

Madan, M.L., Comparision of performance on a tracking task utilizing binocular, dominant and non-dominant viewing. Student thesis, United States Naval Postgraduate School, 1980

Poulton, E.C., Engineering psychology, *Anual review of psychology*, vol.17, pp. 177-200, 1966

Poulton, E.C., Tracking behavior. in *Acquisition of skill*. Bilodeau, E.A.(Ed). New York : Academic press, 1966A

Poulton, E.C., *Tracking skill and manual control*. New York : Academic press, 1974

Siegel, S., *Nonparametric statistics for the behavioral sciences*. New York : McGraw-hill, 1956

Sperling, G., The information available in brief visual presentations, *Psychology monographs*, vol.74, no. 11, 1960

Yong, I.C., A study of tremor in normal subjects, *Journal of Experimental Psychology*, vol. 16, pp. 644-656, 1933

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55 Department of Operations Reseach Naval Postgraduate School Monterey, California 93940	1
4.	Asst. Professor D. E. Neil, Code 55Ni Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
5.	LCDR W. F. Moroney, code 55Mp Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
6.	Lt/Col. Yong-Hoon Bahk PPBS Ministry of National Defense Seoul, Korea (140)	1

Thesis 187078
B1366 Bahk
c.1
Comparison of performance on a tracking task under speed or accuracy instructions.